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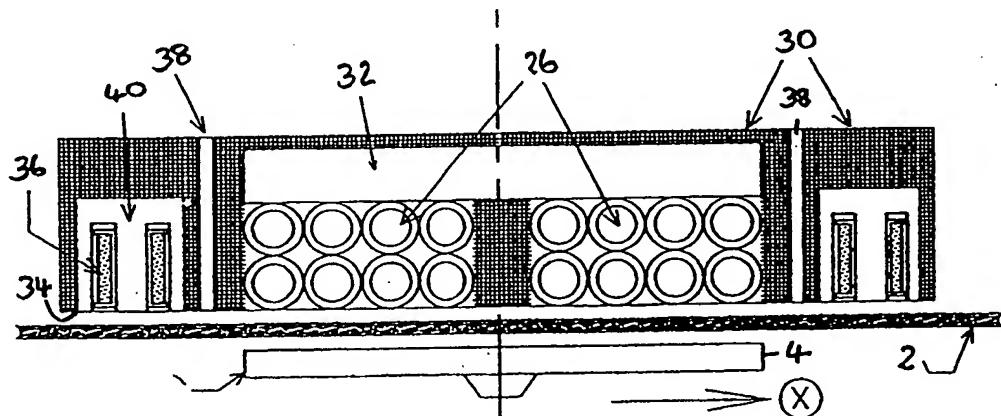
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(54) Title: PORTABLE INDUCTION HEATER



## (57) Abstract

An induction heater having an induction coil (26) for heating a metallic substance (4) hidden by a membrane (2), the metallic substance being coated with a heat activated adhesive on its side adjacent the membrane (2). The heater having four location sensor coils (36) for detecting the position of the hidden metallic substance and means to facilitate the placement of the induction coil (26) over the hidden metallic substance (4), based on information from the sensors. Once the induction coil (26) is over the metallic substance (4) it is used to heat the adhesive thereby adhering the metallic substance (4) to the membrane (2). The sensors (36) are adjacent the inductor coil (26) and are insulated therefrom by an air gap (38).

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### Portable Induction Heater

The present invention relates to portable induction heaters.

Plastic and rubber membranes are utilised for providing waterproofing to roofing structures, tunnels and tanks. In the roofing industry, the  
5 membranes are laid down upon an insulation layer of either rockwool board, plastic resin foam board or even gypsum board, which is itself laid and fixed to the main substructure, which could be concrete, wood or steel sheet. The membranes are fixed either by glue, directly to the insulation boards, as in Fig. 10, or glued to numerous small anchor pads that have been  
10 screwed to the substructure through the insulation boards, as in Fig. 11. The glue is usually a solvent based adhesive, which is toxic and unpleasant to apply and can have unacceptably long curing times in cold climate conditions. Alternatively, the membranes are fixed with screws and suitable washers directly through the edge of each sheet of membrane and into the  
15 substructure through the insulation boards. This has the disadvantage that additional steps must be taken to prevent leakage through the membrane at the points where the fastenings extends therethrough in that the next sheet of membrane laid must cover the screws and fixings and then be heat welded to the previous sheet, as in Fig. 12.  
20 In order to overcome the aforementioned problems a rigid plastic anchor disc, as in Fig. 13, is fixed to the substructure through a pad of

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membrane and on through the insulation boards. The membrane pad is substantially larger than the anchor disc and has received a factory coating of heat activated adhesive mixed with a powdered metallic substance on the upper surface of the pad that is clear of the anchor disc. It is also possible  
5 that the metallic powder may be incorporated within the substance of the membrane pad at the time of manufacture. The main covering membrane overlays the anchor and membrane pad.

The powdered metallic substance is heated by an induction heater which glues the membrane pad to the overlaying membrane, thereby  
10 entrapping the plastic anchor disc and anchoring the membrane. Alternatively a metallic anchor disc can be used as in Fig. 14.

UK Patent Application No. 9506694.09 (Robertson) describes the use of an induction heater to perform the bonding operation, however it is impossible to locate the induction coil of the induction heater reliably and  
15 accurately over the metallic anchor disc or powder that requires heating (within 1mm), because it cannot be seen underneath the membrane. Failure to guarantee accurate location causes one part of the anchor disc overheat and burn the adhesive whilst the other half is under heated and not properly bonded. Inaccurate placement could cause over-heating damage to  
20 both the adhesive and the membrane, whilst under-heating would not provide sufficient bond strength. Either of these conditions could cause the failure of the roof over an extended time scale but particularly during high

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wind conditions.

It is an object of the present invention to overcome or alleviate the above described drawbacks and to provide for more accurate placement of the induction heater over the metallic substance to be heated.

5        In accordance with the present invention there is provided an induction heater for heating a hidden metallic substance, the heater having an induction coil for remotely heating a metallic substance, a sensor for detecting the position of said hidden metallic substance and means to facilitate placement of the induction coil directly over the hidden metallic  
10      substance based on information provided from said sensor.

The accurate placement of the induction coil over the hidden metallic substance to be heated reduces the incident of operator error and in the case of anchoring roofing membranes to the main roof structure by the use of fixed underlying metallic discs coated with heat activated adhesive, the accuracy of placement of the induction head bears a direct relationship to the strength of the anchor's bond to the membrane, reducing the incidence of the membrane coming away from the roof in high wind conditions and reducing the amount of time needed to secure the membrane to the roof.  
15

20       Preferably, the means to facilitate the placement of the induction heater comprises a visual display which indicates the direction the heater must be moved to bring the induction coil over the hidden metallic substance. Preferably, the means to facilitate comprises means to provide

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an audible signal to indicate the progress of the heat cycle.

Preferably the sensor is adjacent the induction coil and insulating means are provided to reduce the flow of heat from the induction coil to the sensor. This reduces damage to the sensor during operation of the induction coil. The insulating means can be an air gap between the sensor and induction coil and/or cooling means provided to cool the induction coil. In a preferred embodiment the induction coil is in the form of a tube which provides a path for flow of a coolant. Preferably said path extends beyond the induction coil and passes through a heat exchanger.

Preferably the induction heater is portable and has a manually directable induction head containing the sensor and the induction coil, which head is connected to a main control box by a flexible cable.

A micro processor controls all the functions of the induction heater as well as the continuous monitoring of operating and fault conditions.

A very stable crystal controlled sine wave generator is used to provide the electromagnetic field for the location sensors. This sensor frequency drive is connected to the main induction coil, (or a separate coaxial auxiliary coil if the physical constraints of the size of the metallic substance do not allow use of the induction coil), at all times, except when the heat cycle is in operation. A relay operated by the micro computer disconnects the sensor frequency drive before heating and reconnects it again after heating.

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Preferably, the sensor is a four quadrant metal detection device having in a preferred embodiment four, separate, sensing members placed at opposite ends of two radial orthogonal centre lines about the vertical axis of the induction coil with their sensing poles on the same plane as the lower face of the induction coil. The sensor members on radially opposite sides of the induction coil are treated as a pair. There are two configurations of the assembly which are as follows:- Where it is required to heat a flat metallic object evenly, over its surface, to its centre, then the sensing members would be distributed evenly about the external radius of the induction coil, however, if it is required only to heat an external ring of metallic substance then the sensing members may either be distributed within the internal radius of the induction coil, providing there is sufficient space, or externally as before. In a preferred embodiment, the sensing members are sensing coils. This has the advantage that sensing coils are very sensitive and require little amplification.

In a second embodiment the sensing members are hall-effect sensors. This has the advantage that the hall-effect sensors can sense very low frequencies, or variations in a static magnetic field. This is particularly advantageous if the anchor is mounted to an aluminium foil coated insulation board. If sensor coils are employed in the heater the high frequency used may cause the coil to detect the aluminium foil as if it were a continuous metal disc or anchor which may make it more difficult to

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locate the centre of the anchor from the background signal of the foil. The lower frequency sensed by the hall-effect sensors allows the use of aluminium foil coated insulation board, without giving erroneous readings. Furthermore, hall-effect sensors do not require tuning.

5            Preferably a high performance induction grade of ferrite is formed into a protective cover over the top surfaces of the induction coil to provide a low impedance magnetic path to the underlying metallic substance, in order to increase the flow of magnetic flux during location and the induction heating process and to also provide safety screening for EMC and adjacent  
10            personnel.

Preferably each of the sensor coils has capacitors added in order to make it resonate at the sensor frequency which is considerably different to, but not a harmonic of, the induction coil frequency.

During location of the metallic substance, the induction coil itself, or  
15            a separate auxiliary coil coaxial with the induction coil, is energised at the sensor frequency by a suitable low power signal source which is disconnected automatically prior to the induction cycle to prevent damage. The resonance of the sensor coils allows the voltage pick-up sensitivity to be greatly increased, which allows for the detection of a metallic substance  
20            over a greater distance.

The sensor members are mechanically placed to pick up equal voltages when the metallic substance to be detected is situated exactly

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central with the induction coil. The presence of a metallic substance within the sensor frequency field alters the pick-up voltage on each of the sensor members in relation to the position of the metallic substance beneath the induction coil. The pick-up voltage of each sensor member is fed into a microprocessor via a conditioning circuit and the value of each reading can be used by the microprocessor to calculate co-ordinates of the centre of the metallic substance in relation to the centre of the induction coil, providing the metallic substance is within range. These co-ordinates would allow the microprocessor to drive said visual display which would facilitate manual placement of the induction coil and also in a further embodiment the driving of X and Y axis motors to provide for automated operation.

The microprocessor also subtracts each sensor member reading from the result of the opposite sensor coil. If the result of the subtraction is zero or within an acceptable low band of numbers then the metallic substance is centrally disposed below the induction head in the line joining the two opposite sensor members. Similarly the orthogonal pair of sensor members are measured. If both pairs of sensor members produce a central result then after a number of similar successive stable readings the microprocessor would consider the metallic substance to be centrally disposed below the induction coil and initiate the next step required in the induction heating cycle. The use of opposite pairs of sensor members allows the subtraction process to cancel out any temperature drift in the system.

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Preferably, the whole assembly consisting of the induction coil, the auxiliary coil if utilised and the sensor members is completely encapsulated in a suitable potting compound such as a low exothermic epoxy, which ensures a very robust device. In order to reduce the conduction of heat from the induction head to the sensor coils via the potting compound, air slots are moulded into the region between each sensor coil and the adjacent coil windings. To cool the induction coil a gap can be provided between the induction coil and encapsulant for the flow of coolant about the induction coil. In a preferred embodiment the induction coil is constructed from a tube which provides a path for the flow of coolant.

When the induction heater is used to heat a metallic anchor beneath a membrane, for the purpose of bonding the membrane to the anchor, the membrane takes up considerable heat from the anchor plate. This localised heat causes the membrane to expand in this area. During the heating process the pressure of the induction heater on the membrane upper surface is sufficient to keep the membrane in intimate contact with the anchor. At the end of the heat cycle if the induction heater is removed to another anchor location before the bond is set the membrane is free to rise up away from the anchor. A bag of sand or a heavy flat bottomed object may be placed on top of the membrane/anchor location, to prevent the membrane rising away from the anchor until the anchor and membrane have cooled down and the bond has formed between the two.

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Unfortunately, this method has several drawbacks. Firstly, the top of the membrane is very hot and an unsuitable material placed on top will produce unsightly deformation in the membrane surface. Secondly, it is critical to the quality of the bond that the pressure on the membrane surface is even over the area above the anchor. Thirdly, the pressure on the membrane surface over the area of the anchor is ideally not less than 5Kg, in order to produce a satisfactory bond. Fourthly, these simple means will not function on sloping, vertical or inverted surfaces such as a pitched roof, walls or tunnel linings.

In accordance with a second aspect of the present invention there is provided a magnetic membrane clamp for holding the membrane to an anchor until the bond between the two has set. This has the advantage that the clamp is held in position by its magnetic attraction to the anchor and thereby is suitable for use on inclined surfaces.

Preferably, the clamp has a substantially flat surface to its base. This reduces the incidence of unsightly markings to the surface of the membrane. Preferably, the surface of the base of the clamp is larger than the surface area of an anchor. This has the advantage of providing a flat appearance of the membrane surface in the vicinity of the anchor.

Preferably, the clamp comprises a ring magnet coincident with the bond area of an anchor. Preferably, the ring magnet comprises a plurality of individual magnets whose polarity is placed in an alternating fashion

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about the ring. This has the advantage of an increased magnetic force, with prolonged life. Preferably, the magnet is an electro-magnet and means are provided to switch the magnetic field on and off. This has the advantage that the operator can switch off the magnet when he wishes to remove the clamp from a bonded area.

Preferably, the clamp comprises a heat sink. This has the advantage that heat transferred to the clamp from the anchor can be readily dissipated to the ambient.

Preferably, the clamp comprises an elongate handle. This facilitates the placement of the clamp without the need for the operator to stoop.

By way of example only, specific embodiments of the present invention will now be described, with reference to the accompanying drawings, in which:-

Fig. 1 is a perspective view of an induction heater, constructed in accordance with one embodiment of the present invention, illustrating the heater in place over a membrane;

Fig. 2 is a perspective of the heater head of the induction heater of Fig. 1, with an enlarged detail of its location display, and illustrating the heater in place over a disc to be heated, the roofing structure being shown in cross-section;

Fig. 3 is a sectional view of the head of Figs. 1 and 2;

Fig. 4 is a schematic plan view of the induction head for locating and

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heating discs;

Fig. 5 is a sectional view along the direction y-y of Fig. 4;

5 Fig. 6 is a graph of sensor peak output voltage on the centre vertical axis plotted against position of the metal anchor disc from left to right through the central position, on the horizontal axis. (The graph only shows the traces for one pair of sensor coils, the orthogonal pair of sensor coils have identical traces);

Fig. 7 is a schematic of the circuit layout of the induction heater;

10 Fig. 8 is a schematic view of the cooling system of the induction heater;

Fig. 9 is a block diagram providing an indication of the circuitry of the main box and induction head of the induction heater;

15 Fig. 10 is a schematic view of a known system for fixing a membrane to a roofing structure;

Figs. 11 to 15 are schematic views of further systems for fixing membranes to roofing structures;

Fig. 16 is a view similar to Fig. 5 illustrating a second embodiment of induction heater utilising an alternative sensor;

20 Fig. 17 is a view similar to Fig. 16 illustrating a different arrangement of the sensors;

Fig. 18 is a schematic view of a magnetic clamp in situ on a

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membrane/anchor boarding point; and

Fig. 19 is a schematic view of the clamp of Fig. 18.

To fit a single or multi-layer membrane 2 to a roof structure a plurality  
5 of circular steel anchor discs 4 are firstly screwed to a roof substructure 6  
through thermal insulation blocks 8, the top surface 10 of each anchor disc  
4 being pre-coated with a heat activated adhesive. The membrane 2 is then  
rolled across the roof structure thereby concealing the discs 4. A remote  
electromagnetic induction heater 12 above the membrane heats up the  
10 anchor disc 4 whereby the adhesive is activated and adheres the membrane  
2 to the disc 4.

The induction heater, as best illustrated in Fig. 1, comprises a  
rainproof main box 14, a heavy duty, demountable, flexible cable 16 and an  
induction head 18.

15 The induction head 18, see Fig. 3, comprises a plastics body 20  
having a handle 22 to allow manual placement at a desired location. A cable  
socket 24 is adapted to receive one end of the cable 16.

The head 18 has an induction coil 26 in the form of a two layer  
pancake, formed from copper tubing, the tubing extends at 28 in the form  
20 of two silicon tubes to permit flow of a cooling fluid through the induction  
coil 26.

The cooling system, see Fig. 8, has several high pressure fans 60

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blowing air at ambient temperature through fins of a heat exchanger 62 within box 14 and which cools the fluid that is pumped around the closed circuit by a small circulating pump 64. This fluid is used to cool the electronic drive circuit switching devices and also to remove excess heat  
5 generated in the induction coil 26. An expansion reservoir 66 allows for topping up the fluid and viewing of the fluid level by an operator, via a window (not illustrated).

The closed circuit comprises the induction coil 26, additional tubing 28 and extends via an inlet and outlet tubes 67, 69 extending through the  
10 cable 16 to box 14. Each pipe carrying coolant through the cable 16 have self closing plugs and sockets 68 to facilitate disconnection of the cable 16 without losing coolant from the system.

The coil 26 is encapsulated in epoxy resin to form a rigid structure  
30. A ferrite pad 32 is provided on top of the coil 26 to provide a low  
15 impedance path for the magnetic flux in the coil 26, and thereby provide a screen, from the magnetic field, for the operator. A self-adhesive PTFE coated glass woven cloth 34 is provided on the lower surface of the head 18 to provide a low friction surface for sliding the head 18 across the membrane 2.

20 Four location sensor coils 36 are also encapsulated within the body  
20. To prevent the flow of heat through the encapsulant from the copper induction coil 26, a narrow air slot 38 is moulded into the encapsulant

between each sensor 36 and the adjacent windings of the coil 26.

As best illustrated in Fig. 5 each sensor 36 is enclosed by an individual high grade ferrite core 40 and provides the pole pieces on the same bottom plane as the induction coil 26. In Fig. 4 each sensor coil is 5 separately named A, B, C or D. A and B is one pair, C and D is the other pair.

Tuning capacitors 42 are connected to each sensor coil to tune it to the sensor frequency of 9.7 kHz (in this example). The induction coil frequency is 53 to 55 kHz, rather different from the sensor frequency.

10 The position of each sensor core 40 can be mechanically adjusted during manufacture, along its radial centre line towards the induction coil 26, to achieve a peak output voltage which all four sensor coils 36 can achieve.

In this particular example the voltage was set at about 1.6 volts as 15 shown on the graph in Figure 6. It can be seen from the graph that as the induction coil assembly is moved over the metal anchor disk 4 from 200 millimetres off centre to the right, through the centre and on towards the left hand -200 millimetre position, that the voltage pick-up on each coil of the pair, only crosses at the 1.6 volt position which coincides with the central location. A microprocessor 44 continually reads the voltages on 20 each sensor coil 36 and uses the values to drive a display 46 that shows the centre of the anchor disc 4 in relation to the centre of the induction coil

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26. This display 46 allows a manual operator to move the induction coil assembly until the centres coincide. In an automated version, X and Y axis motors are driven from these values to move the induction coil assembly.

5           After each read the microprocessor 44 tests for equality between opposite sensor coils 36 of each pair A B or C D that occurs below the cut-off voltage, which is 2.2 volts in this example. If both pairs of sensor coils produce an equal result then after a number of similar successive stable readings the microprocessor 44 would assume that the anchor disc 4 is central with the induction coil 26. The microprocessor 44 would set a software latch, then initiate the disconnection of the sensor frequency drive 73 by opening switch 48 in Fig. 7, apply protection to the conditioning circuits 50, 52, 54 and 56 and then enable an induction heating generator 58 which drives the main induction heater coil 26.

15          At the end of the induction heating cycle time the induction heating generator 58 is disabled by the microprocessor 44. The sensor frequency drive 73 is reconnected to the induction coil 26 by switch 48 and the protection is removed from the conditioning circuits 50, 52, 54 and 56. The microprocessor 44 continues to read the sensor coils 36 and only when the 20 readings are above the cut-off voltage of 2.2 volts, in this example, is the software latch released. This software latch arrangement is to prevent the induction heat cycle being repeated unless the induction head 18 is

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completely removed from the last anchor disc location, otherwise the same anchor disc will be repeatedly heated.

Any one or more of outer four display lights on display 46 on the head 18, illuminating when the induction head 18 is swept over the membrane surface, indicates the presence of a metallic substance within 150mm, see Fig. 2. The head 18 is then moved in the direction of the illuminated lights until only the centre red light 47 is illuminated. At this point, provided that the head 18 is sitting flat on the membrane 2, the anchor disc 4 will be centrally disposed about the centre of the induction coil 26.

If a metallic object, other than the anchor disc that the head 18 was designed to detect, is picked up, the centre light 47 will not illuminate, thus preventing false heating.

The software latch is provided to prevent a repeat heat cycle of the same anchor disc 4. The head 18 must be completely removed from any metallic substance, for a preset time, to extinguish all the red lights before the location and heat cycle can be continued with the next anchor disc 4.

During location, when the centre light 47 alone, has been illuminated for a preset time, the heat cycle will be automatically started. This delay is to prevent heating if there is subsequent accidental movement.

Whilst the heating cycle is in progress, the centre red light 47 will extinguish and the outer red display lights 49 will provide a rotating effect

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to indicate that heating is in progress.

At the same time as the heating is in progress a low frequency audible tone will pulse with each passing second to alert the operator not to move the head. The sounds emanate from a loudspeaker 70 mounted in  
5 the main induction heater box 14.

When the heating time has ended, a combination of higher frequency pulse tones are emitted from the loudspeaker 70 to tell the operator that the heat cycle has finished and that he should proceed to the next location. At the same time, the rotating display 49 of red lights ceases and the centre  
10 light 47 illuminates again until the head 18 is removed from the vicinity of the disc 4 that has been heated.

If the head 18 were to be removed from the location of the anchor disc 4 whilst still in the heating cycle, then the induction current would fall below a minimum preset limit and the heat cycle would be immediately terminated and this fact indicated by the fault light on a control panel 72 of  
15 the main box 14 being illuminated. If the head 18 is completely removed from the metallic substance 4 then the fault light will be extinguished and operation can be continued normally.

If the induction current in the head 18 were to rise above a preset limit, then the heat cycle will be terminated immediately to prevent damage  
20 to the equipment and a software lock-out latch set. This is indicated by the fault light on the control panel 72 of the main box 14 being illuminated. No

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further heat cycles are possible unless this lock-out is cleared, by switching the mains power off and then on again after a 5 second delay.

If the mains supply voltage were to fall below a preset limit then the heat cycle would be prevented or immediately terminated and this fact indicated by a slow flashing fault light on the control panel 72 of the main box 14, see Fig. 9.

If the mains supply voltage were to rise above a present limit, then further heat cycles would be prevented but an existing cycle would be completed and this fact indicated by a slow flashing fault light on the control panel 72 of the main box 14.

The fault light will be extinguished and it's prohibitions will be removed if the cause of the fault is corrected or removed.

Two electronic counters, are viewed by means of an 8 digit liquid crystal display on the control panel 72. The first counter must be pre-loaded, by use of the buttons on the front panel, with a number of heat cycles that are required. Each heat cycle that is carried out causes this counter to decrement and the balance is displayed. When all the cycles are done and the counter displays zero, no further heat cycles will be possible until a new number is entered. Before a new number can be entered, a pre-determined code must be entered via the buttons, to provide some degree of security against accident or unauthorised use. By entering this code, access is provided to a number of other functions which include setting the

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heat timer, viewing the original number of heat cycles that had been entered before the counter was decremented and also the number of cycles done since the new number was entered. This code can itself be changed, using the buttons, by entering a master code first and then entering a new code,  
5 which is then retained in memory until changed again.

The second counter displays the total number of heat cycles that the machine has ever done in it's life. This counter is non resettable and can be viewed for 5 seconds when the accept button is pressed once, on the control panel. After 5 seconds the display will revert to its previous display.

10 The heat timer can be set via the buttons and by using the code. The time can be set to 2 decimal points of a second, to allow small increments and to any suitable maximum number of whole seconds.

It is also possible to divide the heat time into smaller sections with a delay between each section. The number of divisions and the time of each  
15 delay is adjustable via the buttons on the control panel 72 eg. Instead of one pulse of heat for 10 seconds, it may be better to have 2 pulses of 5 seconds with a delay of 3 seconds in between, to allow the membrane time to absorb the heat.

A high pitched pulse of tone is emitted each time a button is pressed,  
20 to provide operator feedback.

Two power lights are provided on the control panel 72. A large orange light shows that there is power available to the box 14. If this light

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is extinguished, then the power supply to the box 14 is at fault and the operator must sort it out. If this light is on but the small green light is off, then a fuse has blown in the power supply inside the box and it will have to be returned for repair.

5

The heating cycle starts when the micro processor 44 within the box 14 operates a relay that applies 110v power to an induction generator 58 via a current sensor 80. After a preset delay, the micro processor 44 releases the electronic shut-down. This starts the generator 58 at very low power which rises to full preset power at a controlled rate, thus preventing a sudden current surge.

When the heating time is ended, the shut-down is operated, which stops the induction current and after a preset delay, the relay will be released, which removes the 110v power. The use of the electronic shut-down means that the relay contacts do not have to switch the full load current, which prolongs the contact life, but they do provide complete isolation when open and are also able to break the full current in the unusual event of the shut-down failing to operate.

The induction current is controlled by the microprocessor 44, by monitoring the current sensor 80. If the current being monitored falls below the preset value, then the microprocessor 44 will reduce the current limit voltage, which allows the induction current to rise back to the preset value.

20

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Similarly, if the current being monitored should rise above the preset limit, then the microprocessor 44 will raise the current limit voltage, thus returning the induction current back to the preset value. This provides a constant current system which compensates automatically should the mains voltage fluctuate or different membrane thicknesses be used and indeed for variations in the metallic consistency of the item being heated.

The microprocessor 44 monitors the induction coil temperature using sensor 65. If the temperature should rise above a preset limit then further heat cycles would be prevented until the induction coil 26 cooled down. 10 This will be indicated by the fault light on the control panel 72 quickly flashing.

The micro processor also monitors using sensor 63 the ambient temperature of air coming into the box 14 through the vents and this data is used to alter the heat time slightly in order to allow for hot or cold weather. This is in order to produce uniformity in heating, regardless of the 15 weather.

Once heating times are obtained by experimentation, for each type of membrane, then these controls will maintain the times over a wide range of conditions and for most countries.

20 Control switches are also provided within the box 14 to aid the setting up and testing during manufacture or repair. These are not available to the user of the equipment.

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One switch is to disable the low induction current cut out, used when tuning the induction generator 58.

Another switch is used to make the induction generator 58 carry out repetitive heat cycles once every 18 seconds. This is to enable the induction 5 generator 58 to be tuned without having to operate the location system.

Another switch is used to disable the power relay to the induction generator 58 which allows for operating the induction generator 58 continuously or at 18 second intervals, at greatly reduced power, by 10 applying a suitable dropping resistor to the test terminals across the relay, again used in tuning the induction generator 58.

A further switch is used to disable the location output from triggering a heat cycle when a test metallic substance is placed centrally below the induction coil 26. This is used to test the display lights on the induction 15 heat 18 and to adjust the offset of each location sensor amplifier to centralise a test metallic sample below the induction coil.

Another switch is used to disable the ambient temperature correction facility to allow an uncorrected time setting to be made at a test temperature, so that the effect of the correction can then be measured.

20 The present system can be used with the anchor plate in Fig. 11 which takes the form of an 80mm diameter galvanised steel disc of any suitable thickness with regard to rigidity with the heat activated adhesive

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factory applied to the upper surface. In Fig. 12, a 40mm galvanised steel anchor disc may be used, with heat activated adhesive factory applied to the lower surface, as shown in Fig. 14. In Fig. 13, the anchor disc is of a plastic material such as rigid PVC or Nylon and could be about 80mm diameter. The membrane pad would be about 150mm diameter and has received a factory coating of heat activated adhesive mixed with a powdered metallic substance on the upper surface of the pad that is clear of the anchor disc. Referring to Figs. 15 and 18, an anchor disc (metallic, metallic loaded plastics, etc) 100 having a heat activated adhesive coating 102 on its top surface, is mounted to an aluminium foil coated insulation board 104 on a roof structure 106. The disc 100 is fixed to the roof substructure (steel, wood, concrete etc) by fixing screws 107 which extend through the aluminium coated insulation board 104 into the roof structure 106. A roof membrane 108 is secured to the disc 100 by the method described herein. Different sizes of induction coil winding would be required to effectively heat the different anchor systems and this is accomplished with interchangeable induction coil assemblies.

Although sensor coils have been described as the means for detecting the position of a metallic substance to be heated, other forms of sensors could be used for example hall-effect sensors.

In a second embodiment of induction heater, as best illustrated in Figs. 16 to 17, the four, separate, ferrite cored sensing coils 36 are

replaced by linear 'Hall-effect' sensors 110. These are very small, robust, silicon microchips, designed to vary their electrical output depending upon the intensity of the magnetic field passing through the chip.

Similar to the previous embodiment the hall-effect sensors are placed  
5 at opposite ends of two radial orthogonal centre lines about the vertical axis  
of the induction coil 26. The sensor 110 bodies may be situated either,  
below a pole piece of the protective ferrite cover 112 and on the same  
plane as the lower face of the induction coil 26 as shown in Fig. 16, or cut  
into part of a ferrite bar 114 forming the ferrite cover 112 and situated  
10 above the induction coil as shown in Fig. 17. The hall sensors 110 on  
radially opposite sides of the induction coil 26 are as before treated as a  
pair. There are two configurations of the assembly which are as follows:-

Where it is required to heat a flat metallic object evenly, over its  
surface, to its centre, then the sensors would be distributed evenly about  
15 the external radius of the induction coil (Fig. 16), however, if it is required  
to heat an external ring of metallic substance then the sensors may be  
distributed within the internal radius of the induction coil (Fig. 17), providing  
there is sufficient space, or externally as before. The protective cover is  
formed from a high performance induction grade of ferrite and is located  
20 over the top surface of the induction coil. This forms a low impedance  
magnetic path to the underlying metallic substance, in order to increase the  
flow of magnetic flux during location and the induction heating process. It

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also provides a safety screen for EMC and adjacent personnel.

During location of the metallic anchor, the induction coil, or a separate auxiliary coil (not illustrated) coaxial with the induction coil, is energized at the normal mains frequency, by a suitable mains transformer, 5 which is disconnected automatically prior to the induction cycle to prevent damage. As before the sensors 110 are mechanically placed to pick-up equal voltages when the anchor or metallic substance to be detected is situated central to the induction coil. The presence of a metallic substance within the sensor magnetic field alters the output voltage from each of the 10 sensors 110, in relation to the position of the metallic substance beneath the coil 26. The output voltage of each sensor 110 is fed to a microprocessor via a conditioning circuit and as before, the value of each reading can be used by the microprocessor to calculate co-ordinates of the centre of the metallic substance in relation to the centre of the induction 15 coil.

As in the previous embodiment the whole assembly comprising the induction coil, the auxiliary coil if utilised and the sensors is completely encapsulated in a suitable potting compound such as a low exothermic epoxy, which ensures a very robust device. Because the hall-effect sensors 20 are more tolerant of temperature variations, when compared to sensor coils, the air slots, previously referred to, are not required in this arrangement.

To facilitate adequate bonding of the membrane to the anchor, after

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the induction heater is removed, that is until the anchor and membrane have cooled down and the bond formed between the two, a magnetic membrane clamp can be used. The clamp 150 is applied to the membrane, over the anchor area, immediately after the induction heater is removed, at the end 5 of the heating cycle, as best illustrated in Fig. 18.

The magnetic membrane clamp 150, as best illustrated in Fig. 19, comprises a smooth flat base 152 to its body 154 which is somewhat larger than the anchor 100 being used, this prevents unsightly marking of the membrane 108 surface and provides a flat appearance of the membrane surface at the bond area. The clamp 150 has a plurality of magnets 156 embedded in the body 154 in a ring coincident with the bond area of the anchor 100. The polarity of the magnets are placed in an alternating fashion to prolong their life and to strengthen the magnetic field. Alternatively, a ring magnet can also be used provided it produces sufficient clamping force. A steel magnetic keeper ring 158, is placed above the magnets 156, in order to complete the magnetic path above the magnets which increases the clamping force between the magnets 156 and the metallic anchor 100. The body 154, is made of a non magnetic material. 15

If the body 154, is made of aluminium, then a heat sink 160 is used 20 to cool the body by air convection as it will become very hot after a number of bonds have been completed. The heat sink 160 is secured to the body 154 by a central screw 162. Heat flows from the body 154, through the

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steel keeper plate 158, and up into the fins of the heat sink 160, where it is dissipated into the ambient air. A plastics heat insulating hand ring 164, is fitted around the outside of the heat sink 160, so as to protect the operator from the hot surfaces when using the magnetic clamp. The 5 plastics ring 164, is brightly coloured, for example in yellow, to provide a clear visual indication of the clamp and thereby prevent a trip hazard.

A long vertical handle, not illustrated, is attachable via the screw 162, to allow the clamp 150 to be used without the operator having to 10 bend down.

In use the clamp 150 is placed over a newly bonded anchor/membrane position and it is held in place by the magnetic force of attraction between its magnets 156 and the metallic or metal containing anchor 100. The clamp can be removed and used for another bond after 15 allowing approximately 3 minutes for the current bond to cool and set. The location of the bond is apparent to the operators due to the discolouration and deformation of the upper surface of the membrane due to the heat. A temperature sensitive dye may be added to the membrane to further enhance the temporary discolouration and to thereby aid the operator in 20 positioning the magnetic membrane clamp.

Although the body 154 has been described as comprising aluminium, other materials could be used, for example epoxy resin which is a heat

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insulating material. In this instance the heat sink is not required. Although permanent magnets have been described, the magnetic force could be supplied by an electro-magnet.

The invention is not restricted to the above described embodiments  
5 and many modifications and variations can be made, for example the induction heater has been described as mains operated, but it could be battery operated. Alternatively the heater could be robotic and fully automated whereby it would perambulate over the surface under its own power utilising built in sensors for direction determination, stopping only to  
10 heat each anchor disc as it is detected. The induction coil has been described as being in the form of a two layer pancake, formed from copper tubing through which a coolant can flow, alternatively the induction coil can be in the form of a flat bar and a gap provided between the induction coil and the encapsulant to provide a flow path for the coolant.

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Claims

1. An induction heater for heating a hidden metallic substance, comprising an induction coil or the like for remotely heating a metallic substance, a sensor for detecting the position of said hidden metallic substance and means to facilitate placement of the induction coil directly over the hidden metallic substance based on information provided from said sensor.
- 5
2. An induction heater according to claim 1, wherein the means to facilitate the placement of the induction heater comprises a visual display which indicates the direction the heater must be moved to bring the induction coil over the hidden metallic substance.
- 10
3. An induction heater according to claim 1 or 2, wherein the means to facilitate comprises means to provide an audible signal.
4. An induction heater according to any one of claims 1 to 3, wherein the sensor is adjacent the induction coil.
- 15
5. An induction heater according to any one of the preceding claims comprising insulation means to reduce the flow of heat from the induction coil to the sensor.
6. An induction heater according to claim 5, wherein the insulating means is an air gap.
- 20
7. An induction heater according to any one of the preceding claims comprising cooling means.

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8. An induction heater according to any one of the preceding claims, wherein the induction coil is constructed from a tube which provides a path for flow of a coolant.

5 9. An induction heater according to any one of the preceding claims, wherein a flow path for a coolant is provided about the induction coil.

10. An induction heater according to claim 8 or claim 9, comprising a heat exchanger and wherein said path extends beyond the induction coil and passes through the heat exchanger.

10 11. An induction heater according to any one of the preceding claims, wherein the induction heater is robotic.

12. An induction heater according to any one of claims 1 to 10, wherein the induction heater is portable and has a manually directable induction head containing the sensor and the induction coil, which head is connected to a main control box by a flexible cable.

15 13. An induction heater according to any one of the preceding claims, wherein the sensor is a four quadrant metal detection device having four separate, sensing members.

20 14. An induction heater according to claim 13, wherein the sensor members are respectively placed at opposite ends of two orthogonal centre lines about the vertical axis of the induction coil with their sensing poles on the same plane as the lower face of the induction coil.

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15. An induction heater according to claim 13, wherein the sensor members are respectively placed at opposite ends of two orthogonal centre lines about the vertical axis of the induction coil with their sensing poles located within the internal radius of the induction coil.

5 16. An induction heater according to claim 13 or 14, wherein the sensing members are sensing coils.

17. An induction heater according to claim 13 or 14, wherein the sensing members are hall-effect sensors.

18. An induction heater according to any one of the preceding claims, comprising control means to control the functions of the induction heater.

10 19. An induction heater according to claim 18, wherein the control means is adapted to disconnect the sensor from the induction coil during the operation of the heat cycle of the induction coil.

20. An induction heater according to any one of the preceding claims, comprising a magnetic screen which provides a low impedance magnetic path between the induction coil and the metallic substance to be heated.

15 21. An induction heater according to any one of the preceding claims, comprising a separate auxiliary induction coil.

22. A method of securing a membrane to a support utilising an induction heater as claimed in any one of the preceding claims, comprising disposing the membrane over one or more metal members, said metal members being coated on its side adjacent the membrane with a heat activated adhesive,

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locating the at least one metal member and inductively heating that metal member to activate the adhesive and adhere the membrane to said metal member.

23. A method of securing according to claim 22, comprising the further

5 step of removing the induction heater and placing a magnetic clamp over the newly heated metal member to hold the membrane to the metal member until the adhesive has set.

24. A clamp for use in the method of claim 22, comprising at least one ring magnet.

10 25. A clamp according to claim 24, wherein the at least one ring comprises a plurality of individual magnets of alternating polarity.

26. A clamp according to claim 24, wherein the magnet is an electro magnet.

15 27. A clamp according to any one of claims 24 to 26, comprising a substantially planar base surface.

28. A clamp according to any one of claims 24 to 27, comprising a heat sink.

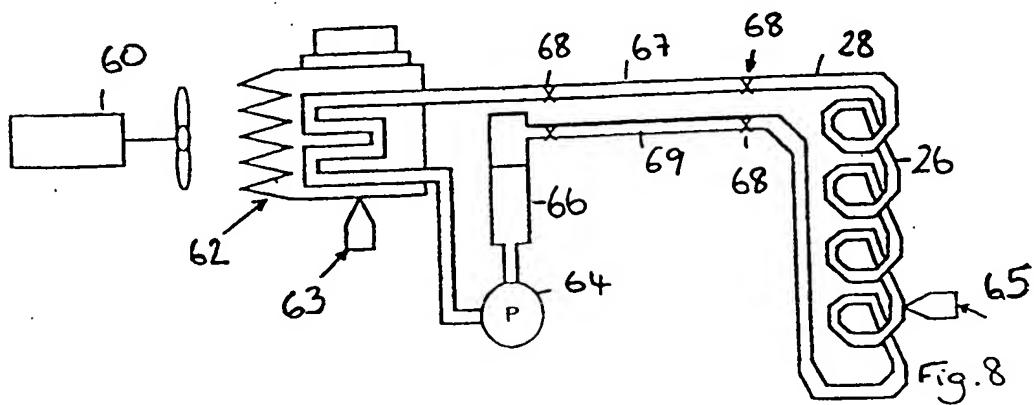
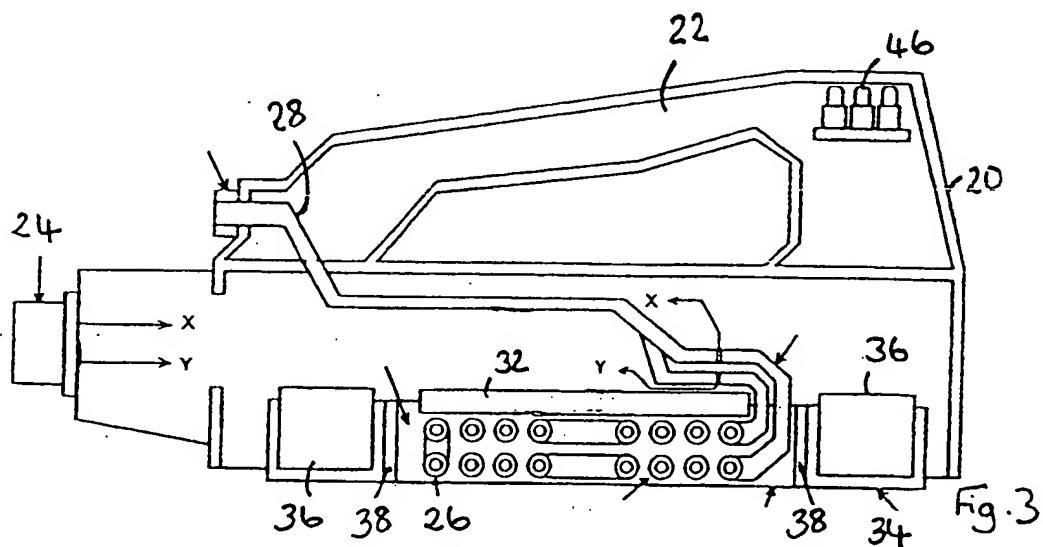
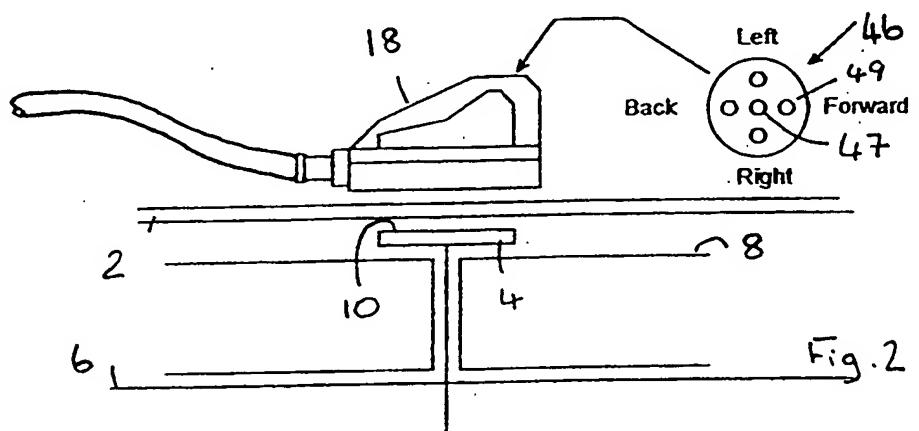
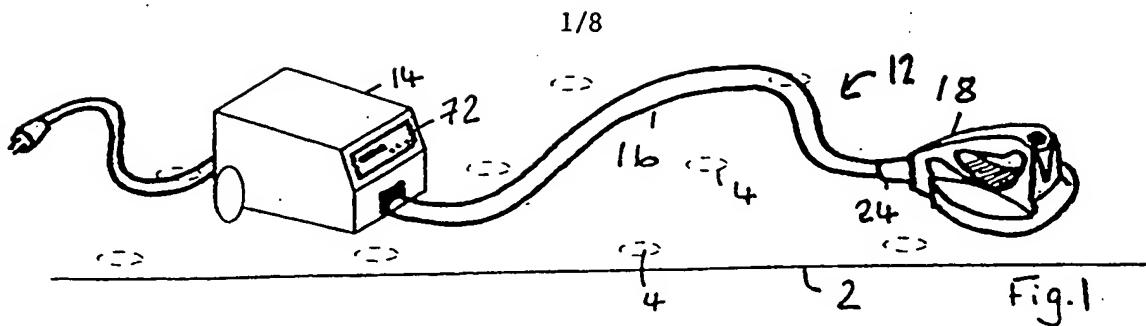
29. A clamp according to any one of claims 24 to 28, comprising an elongate handle.

20 30. An induction heater substantially as hereinbefore described with reference to the accompanying drawings.

31. A method of securing a membrane to a support utilising an induction

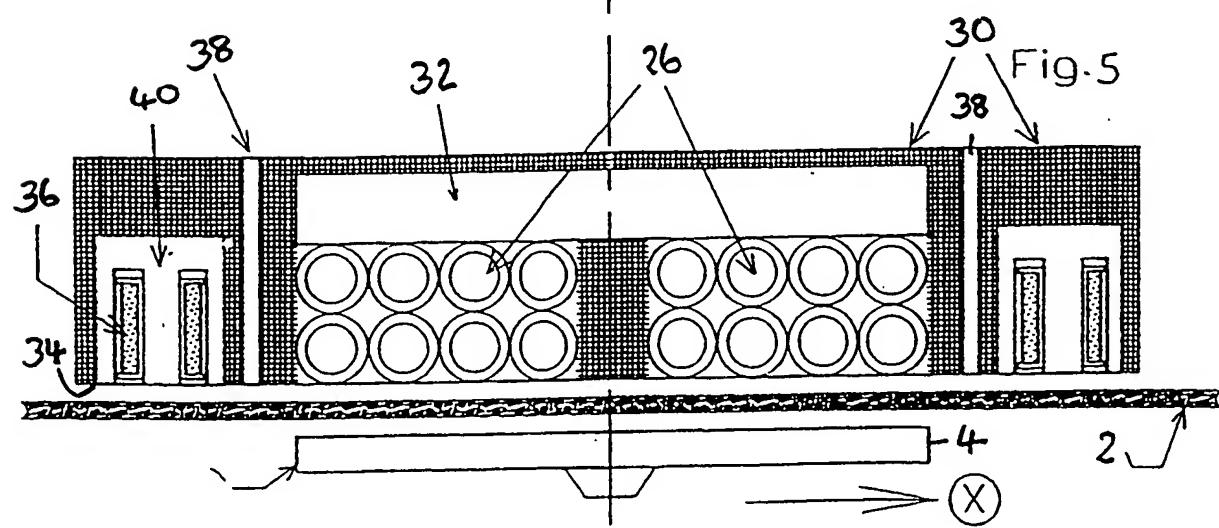
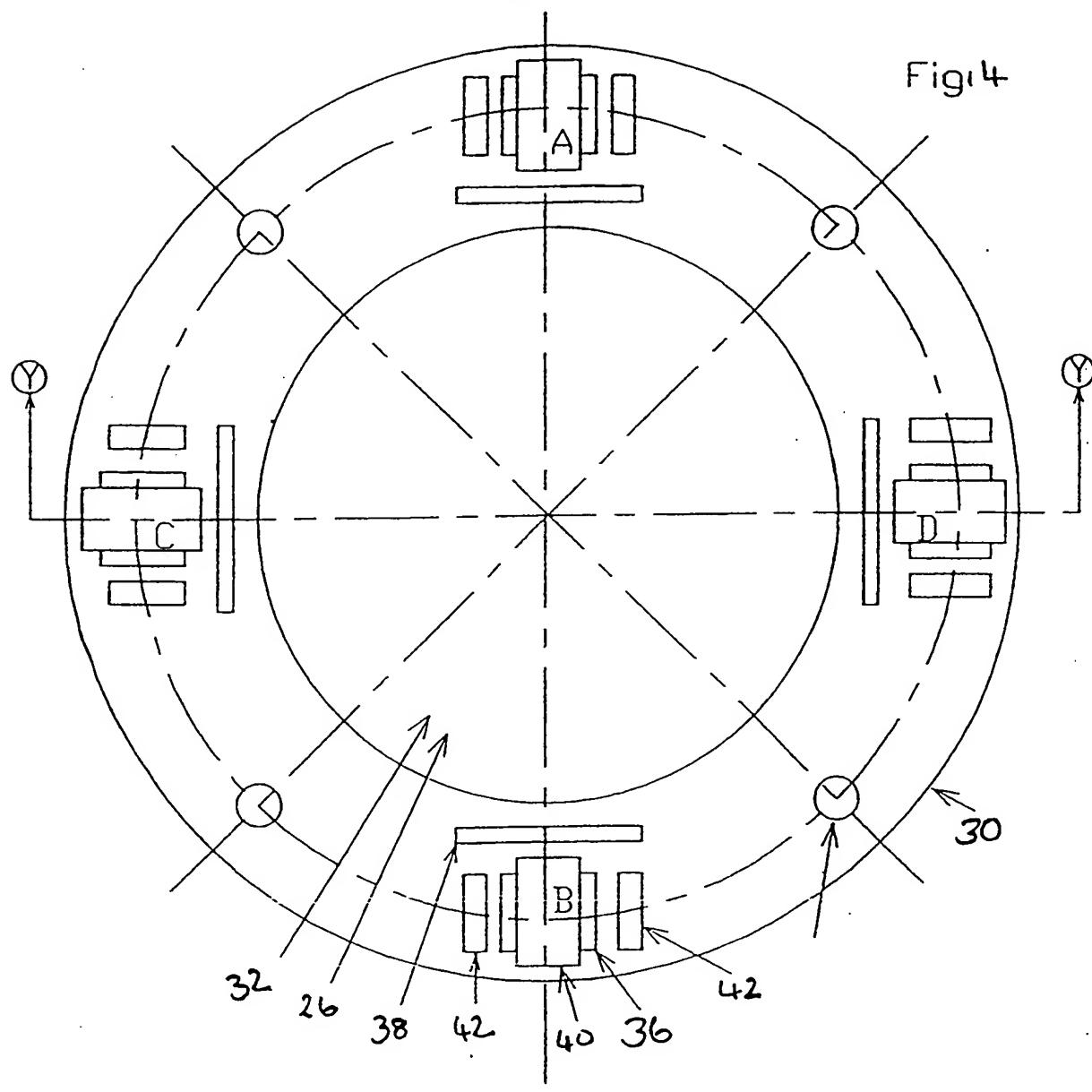
-33-

heater substantially as hereinbefore described with reference to the accompanying drawings.



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Fig.4



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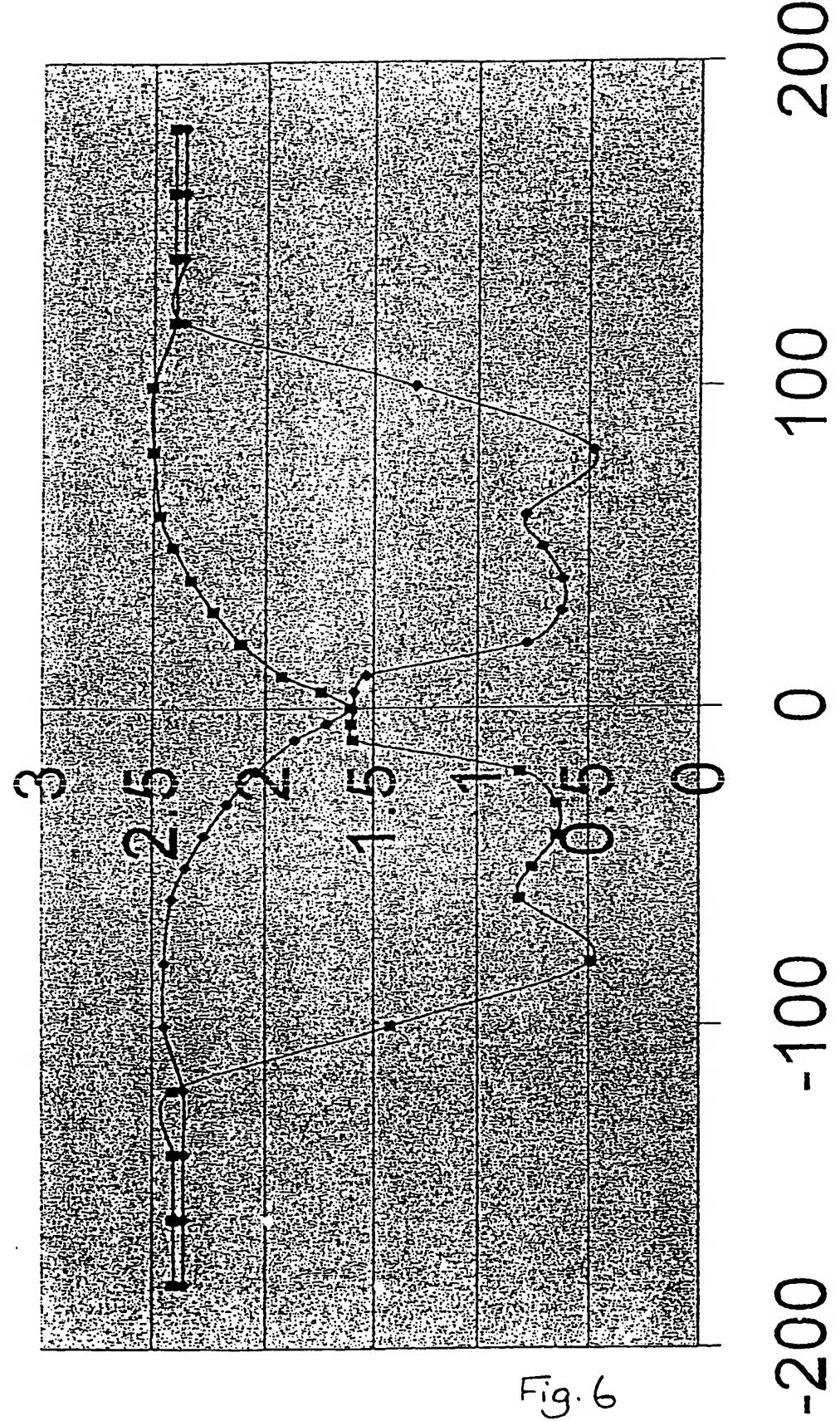
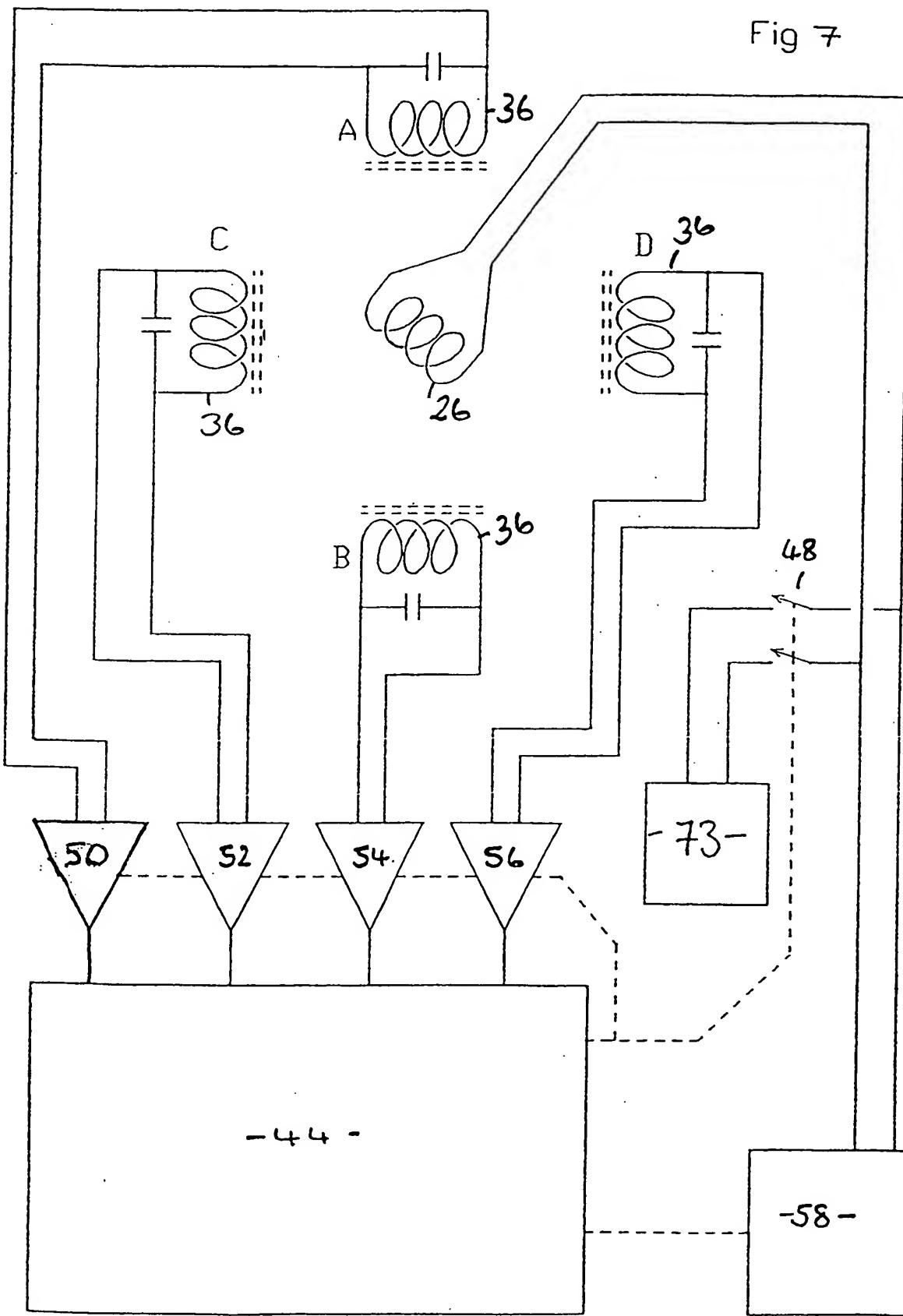


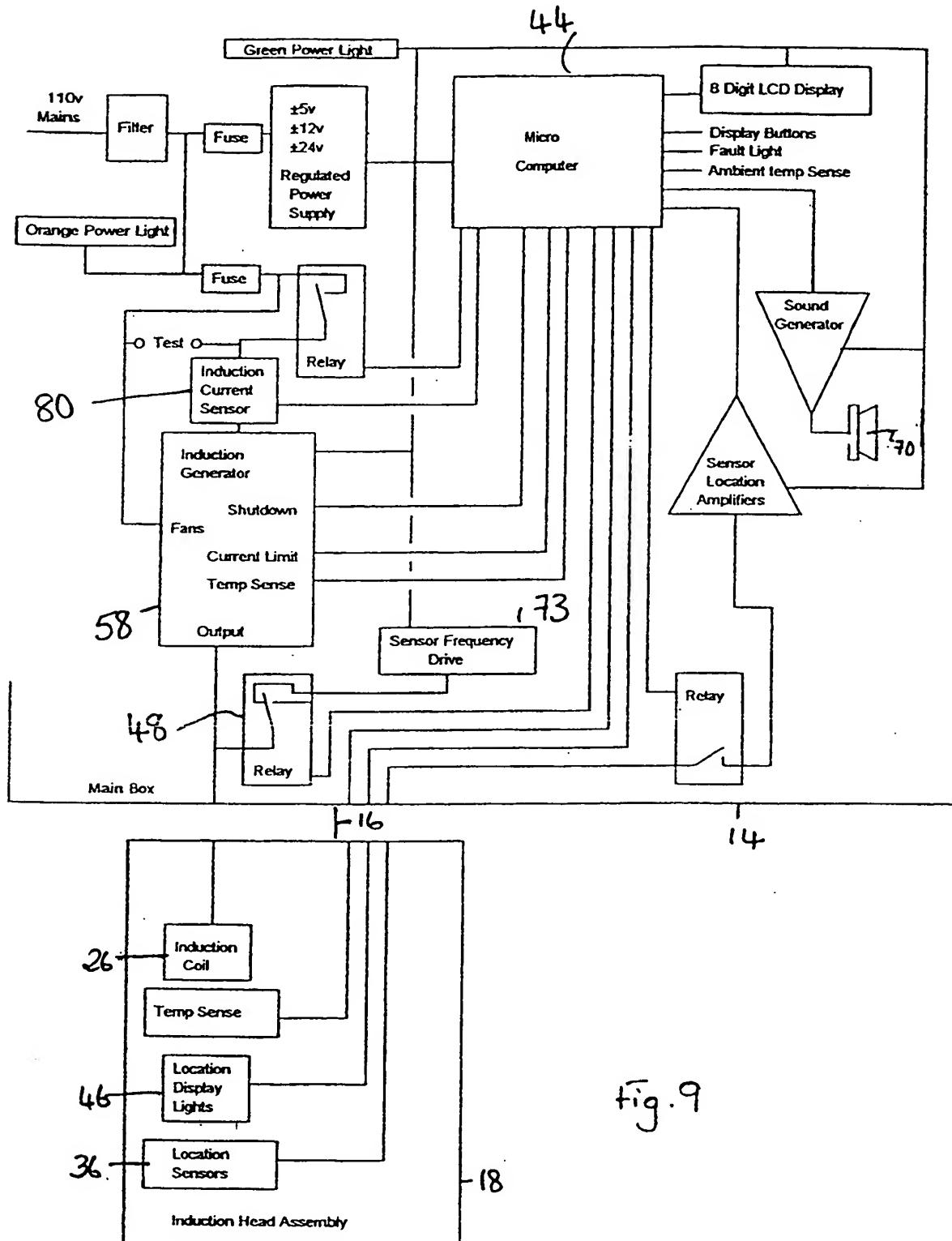
Fig. 6

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Fig 7



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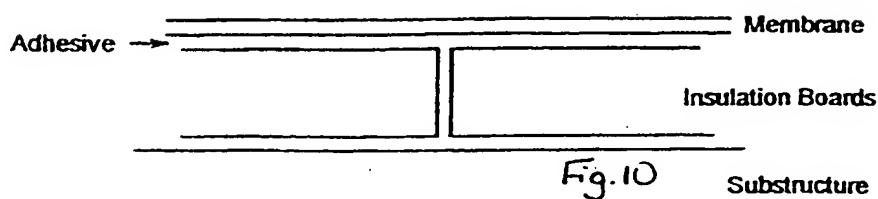


Figure 2.

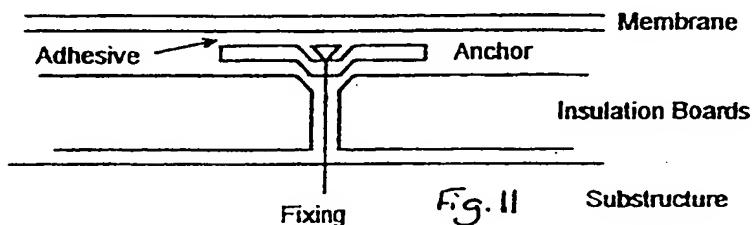
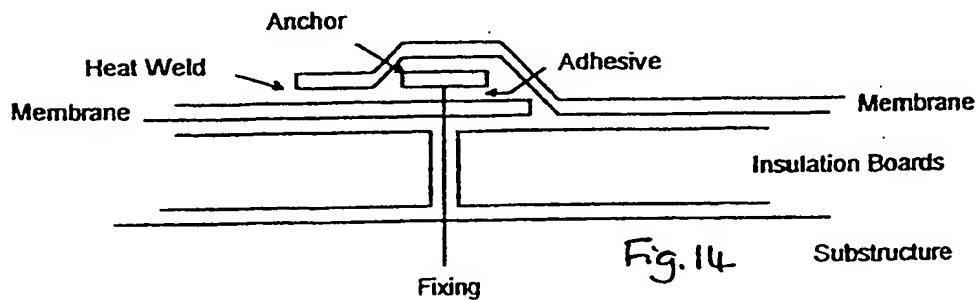
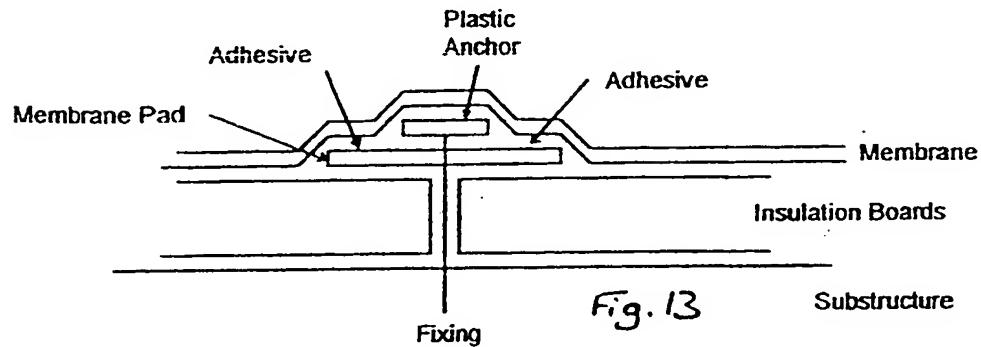
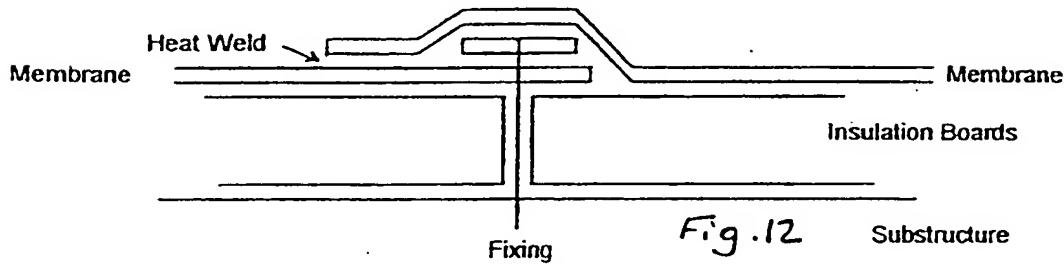


Figure 3.



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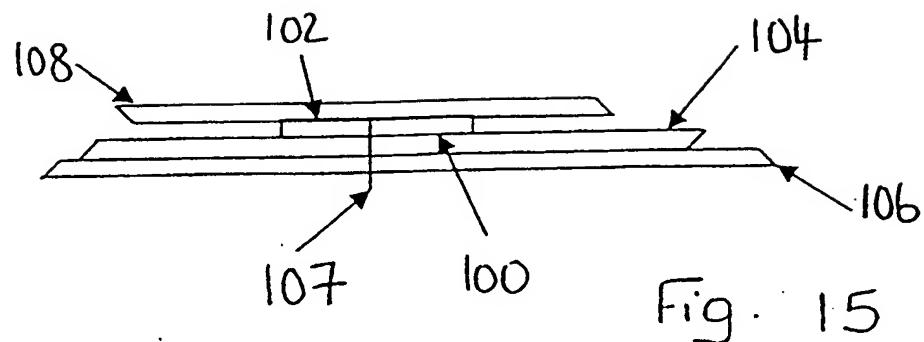


Fig. 15

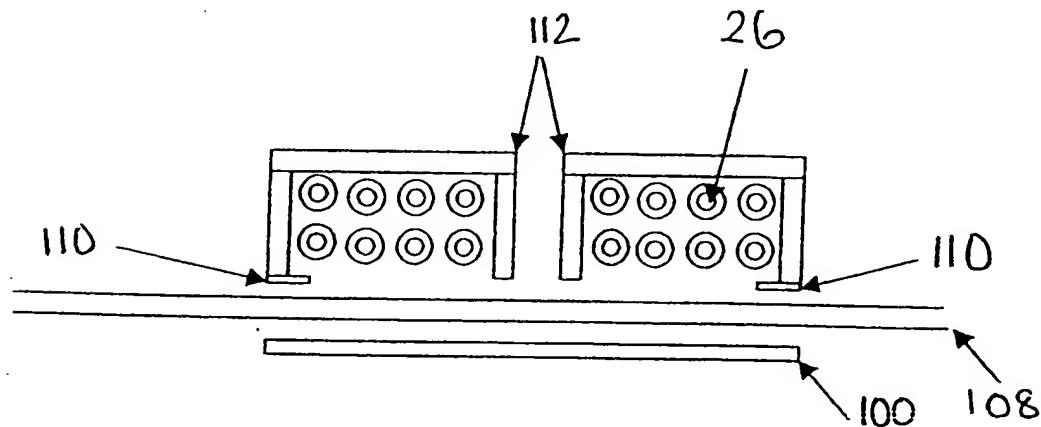


Fig. 16

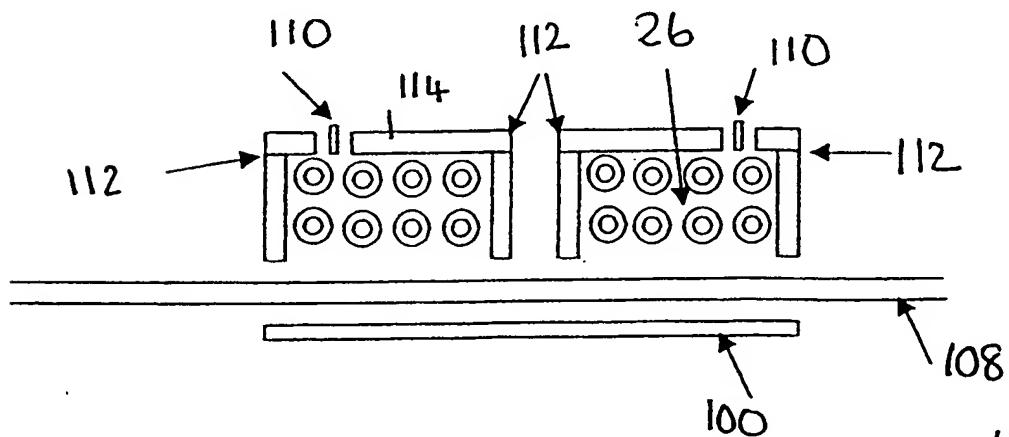


Fig. 17

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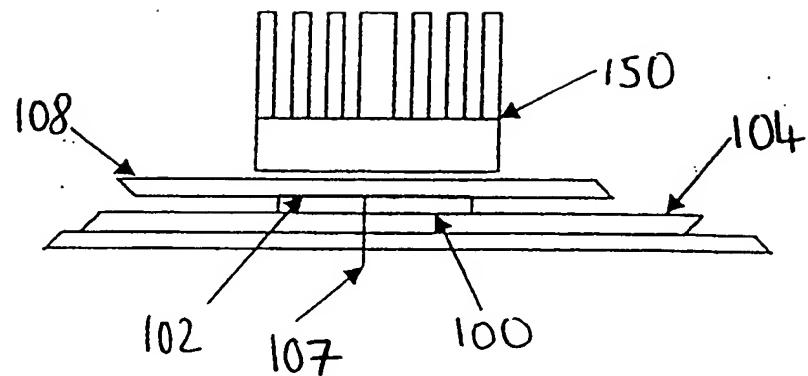


Fig. 18

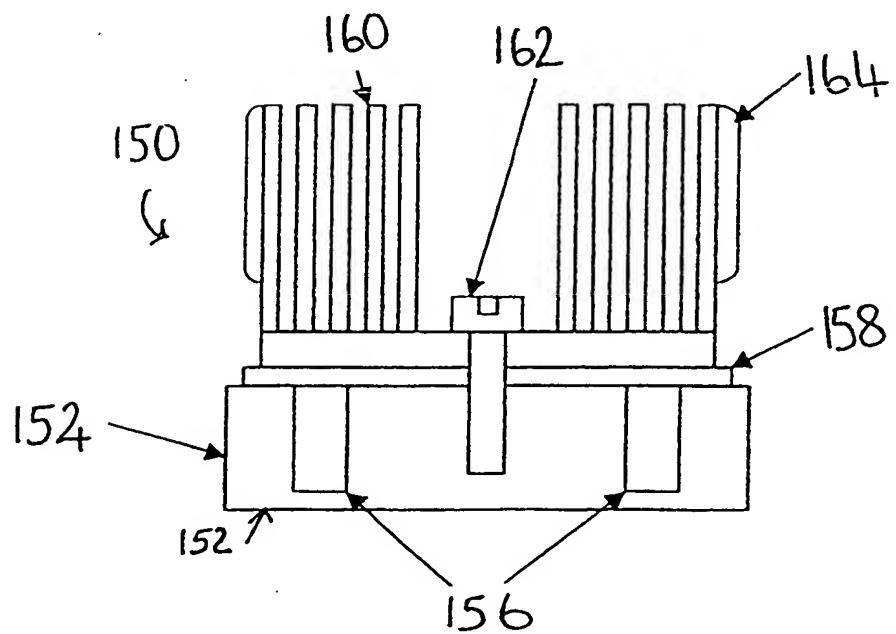


Fig. 19

## INTERNATIONAL SEARCH REPORT

Int'l Application No
PCT/GB 99/01405

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B6/10 G01V3/10 E04D5/14 G01V3/15

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H05B G01V E04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 098, no. 008, 30 June 1998 (1998-06-30) & JP 10 083884 A (SEIDENSHA DENSHI KOGYO KK), 31 March 1998 (1998-03-31) abstract ----	1,2,4,13
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 116 (E-1515), 24 February 1994 (1994-02-24) & JP 05 315064 A (NIPPON KINZOKU CO LTD; OTHERS: 01), 26 November 1993 (1993-11-26) abstract ---- -/-	1,2,22

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

## \* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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17 August 1999

23/08/1999

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## Information on patent family members

International Application No

PCT/GB 99/01405

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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